

First-Year Research in Earth Sciences: Dunes



Evaluation of Stability and Restoration of a Michigan Coastal Dune

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Abstract

There have been a series of studies on the effectiveness of planting vegetation to stabilize dunes, but how well does this management technique restore the natural dune environment? On coastal dunes, *Ammophila breviligulata* is often planted as a management technique to slow dune advance. This study investigated the stability of North Beach dune, Michigan, and compared the natural and planted communities. Dune stability over ten years was evaluated by finding the yearly advance rates using monitoring posts and the change in vegetation cover using ground and aerial photographs. The vegetation was measured to compare height, health, and species diversity between the planted vegetation on the upper windward slope, and the natural vegetation at the lower windward slope. From 2006 to 2016, stability has been established, as indicated by the vegetation, which has covered most of the bare sand, and by advance rates that have slowed. The planted community remained a single species, while the natural community contained a greater number of species. The results indicate planting *Ammophila breviligulata* is successful in establishing stability, but rehabilitating plant communities requires more than ten years to restore species diversity.

Introduction

Ammophila breviligulata (American beach grass) is widely planted to stabilize coastal dunes (Figure 1). *A. breviligulata* is an early colonizer that is able to survive being buried to a depth up to 1 meter of sand (Maun and Lapierre 1984), so it is often planted as a management technique. There have been a series of studies which have investigated the effectiveness of planting dune grass in order to slow dune advance. However, what is poorly understood is how effective planting dune grass is for restoring the dune ecology. This study examined a dune ten years after planting *A. breviligulata* to compare the planted communities to natural ones in order to understand how well planted vegetation restores a dune's natural environment.

The objectives of the study are to:

1. Compare vegetation height, health and species diversity of natural and planted communities.
2. Use ground and aerial photographs to determine the change in percent vegetation cover.
3. Measure the dune advance rate and compare it with advance rates over the previous ten years.



Figure 1. Planted *Ammophila breviligulata* in North Ottawa Dunes, Michigan.

Background

Natural environments have the ability to sustain disturbances up until a threshold and recently, coastal dunes have been reaching their threshold due to the rise in tourism. In 1996, a study indicated that over 30 years approximately 75% of Mediterranean coastal dunes had been either damaged or destroyed as a result of tourism (van der Meulen and Salman 1996). Although the study was conducted on Mediterranean dunes, many Lake Michigan dunes have shared the same experience (Bowles and Maun 1982). One way that tourism affects dunes is by trampling from tourists. Trampling is very damaging to vegetation, with only 200 passes typically eliminating 30% of the vegetation (Talora *et al.* 2007).

The other way tourism affects dunes is by the development of commercial beaches, including raking and building permanent structures. When permanent structures are built, the dune loses some of its ability to regenerate itself (Stancheva *et al.* 2011). Without the ability to restore itself, the dune is at risk because any damages done to the dune will have lasting effects. Similarly, raking disturbs natural processes on dunes. Beach wrack is valuable to the dune ecosystem (Nordstrom *et al.* 2011) because wrack acts as a barrier on the dune to slow the wind, decreasing erosion. Wrack aids in establishing the foredune by causing sand deposition and it promotes the growth of pioneering plant species.

Ammophila breviligulata is often planted to stabilize dunes because it has a 50% survival rate when buried to depths over 60 cm (Maun and Lapierre 1984). Although monoculture plantings of a single species are generally discouraged for restoration projects, on sand dunes, this technique is effective at restoring entire plant communities (Emery and Rudgers 2010). On dunes, the early colonizers will increase the nutrients in the soil allowing for other, larger competitors to grow which will often outcompete for sunlight (Lichter 2000). Early colonizers are necessary because few other species can survive as much sand burial as *A. breviligulata*.

A study conducted on the Ille et Vilaine in Brittany, France found that after a ten years of growing, the planting of dune grass was fast and effective at restoring plant cover (Rozé and Lemauviel 2004). However the ecological diversity took more time to develop. After 95 years, a rehabilitated dune will look more like a natural, undisturbed dune (Landi *et al.* 2012).

Study Area

North Beach dune is a coastal dune located in Ferrysburg, Michigan, in Ottawa County on the eastern shore of Lake Michigan (Figure 2). The dune is well-established with a majority of its arms and leeward slope forested. Before North Beach dune was a part of Ottawa County Parks, the eastern part of the dune was privately owned. From 2005 on, the entire dune is managed by the Ottawa County Parks and Recreation Commission as part of North Ottawa Dunes.



Figure 2. Located north of Ferrysburg, Michigan, the study area is a large parabolic dune known as the North Beach dune because of its proximity to North Beach Park.

In the early 2000s, residents of Ottawa County began to notice the appearance of sand on the only road into the area, North Shore Drive, which connects 300 homes to the rest of Michigan. After some investigation, research indicated the dune was advancing towards the road at a rate of 0.67 meters per year (Jamieson and van Dijk 2004). Ottawa County Park staff implemented management techniques on the dune to stabilize it. One of these techniques was planting *Ammophila breviligulata* (Table 1).

Date	Activity	Source
9 Oct 2004	Volunteer dune grass planting	E-mail records
Sept/Oct 2007	Volunteer dune grass planting	Park Manager's report
19 Apr 2008	20 volunteers planted 1,500-2,000 square feet	Park Manager's report
18 Apr 2009	Volunteer dune grass planting	Spring 2009 park newsletter

Table 1. Partial list of plantings of *A. breviligulata* done in episodes starting in 2004 (data from Swineford *et al.* 2015).

North Beach dune is a highly visited dune with residents and visitors frequently walking the boardwalk on the dune. Prior to construction which extended the boardwalk to the dune crest in 2008, visitors would walk up the dune causing a large amount of trampling which reduced the vegetation cover (Figure 3).



Figure 3. North Beach dune in 2004. The windward slope shows vegetation loss from trampling.

Methods

Vegetation Characteristics

Using GIS, North Beach dune was divided into nine zones of equal area on the windward slope (Figure 4) and six on the slipface. To eliminate bias and determine which zones to measure, a random number generator was used. For the windward side, a number from one to nine, which corresponded to each zone, was randomly generated five times. On the slipface, a number from one to six was randomly generated twice to produce the locations to survey on the dune. Near the end of the study an additional zone was chosen for measurement on the windward slope because it contained planted vegetation, but it was more densely vegetated than the other planted zones. The goal was to see if there were more species growing in a more densely planted community. A total of eight zones (six on windward slope and two on slipface) were measured in order to obtain a broad understanding of vegetation characteristics across the dune.



Figure 4. The windward slope of North Beach dune divided into nine zones and numbered for measurement and analysis. Measurement locations are shown.

Figure 5. Example of healthy *A. breviligulata* in November 2016.



In each zone, a 20-meter transect was measured through the middle of each section parallel to the beach. Along each transect, a 0.5 x 0.5 m quadrat was placed every five meters to measure the characteristics of the vegetation. Vegetation was sampled to determine height, health and species diversity. To evaluate plant health, we measured the average plant health per quadrat using a scale we created from one to five with picture references of each category in healthiness (Figure 5; see Appendix A for complete set of photos). Plant height was recorded by measuring the tallest plants in each quadrat and averaging the values. Species diversity was measured by counting the number of species present within each quadrat.

Change in Vegetation Cover

The change in vegetation cover was measured with aerial and ground photographs. Pictures were chosen based on availability: 2008 and 2016 for ground photos, and 2005 and 2014 for aerial photos obtained from EarthExplorer.usgs.gov. Ground photos were chosen by viewing pictures of the dune from previous years and 2016 that were taken from the same viewpoint and showed as much of the windward slope as possible. Percent cover from aerial and ground photographs were measured by placing a clear plastic grid over each photo. Every grid space that contained bare sand was colored. The total area of the dune in grid squares was measured and the number of squares containing bare sand was divided by the total area of the dune to find the percent of bare sand. The vegetation cover could be found by subtracting the percent of bare sand from the total area.

Dune Advance

To understand how the dune advance rates have changed after planting vegetation on the dune, the position of the leading (eastward) edge of the dune slipface was measured. We

measured the distance from the slipface edge to several monitoring posts that were first installed in 1997, with new posts added in 2005. We also examined almost-yearly measurements of the dune position recorded by Ottawa County Park staff and other researchers. To calculate the dune advance rate, the dune position from a given year was compared with the previous year's results. Then, the dune advance rates were standardized by dividing the amount of advance by the time interval in years from one measurement to the next. Yearly dune advance rates were compared from 1998 to present.

Results

Vegetation Characteristics

North Beach dune is a parabolic dune with forested arms and a wide, open windward slope that is mostly vegetated (grasses) and has some patches bare sand. The bottom of the windward slope has natural, undisturbed vegetation (zones 1, 4, 7) while the vegetation at the upper windward slope was planted (zones 3, 6, 9). The middle slope (zones 2, 5, 8) has a mix of natural and planted vegetation.

Differences in vegetation height and health were negligible between the planted and natural communities. Zones 2, 3, and 9 had the lowest health score of 2, while zones 6 and 7 had the greatest health value of 3 (Figure 6A). In terms of species diversity, the planted communities in zones 3, 6 and 9 remained a single species while the natural vegetation in zone 7 included three species (Figure 6B). The average tallest vegetation was in zone 2 at 89 cm, which was only 13 cm taller than the shortest average tallest plant height at 76 cm (Figure 6C).

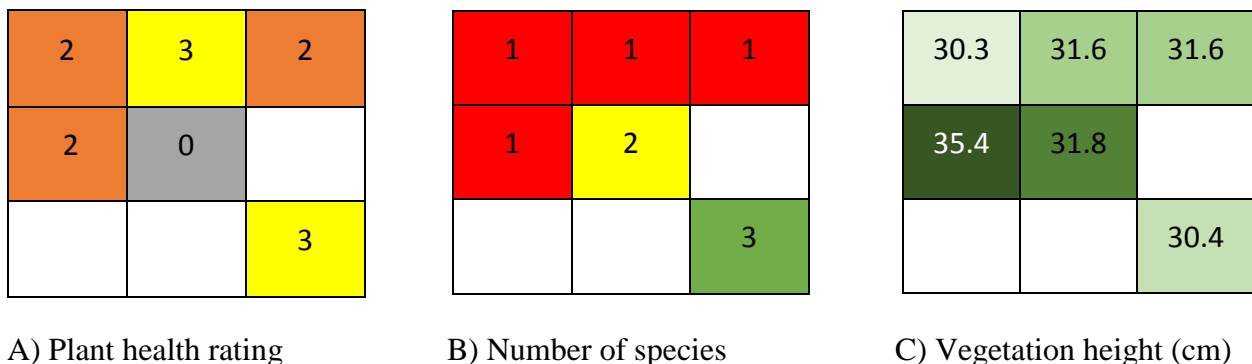


Figure 6. Vegetation results by zone for A) plant health, B) number of species, and C) average tallest vegetation. Orientation is similar to looking at the dune from the bottom of the windward slope, with zones 3, 6, and 9 in the top row, 2, 5, and 8 in the middle row, and 1, 4, and 7 in the bottom row (see Figure 4).

Change in Vegetation Cover

Comparison of ground photos from the years 2008 and 2016 shows a change from 68% to 98% vegetation cover (Figure 7). Aerial photos show the vegetation cover changed from 14% to 68% between the years 2005 and 2014. Ground photos indicate an increase in percent cover of 23% from 2008 to 2016, while aerial photos indicate an increase of 54% from 2005 to 2014.



A) 2005

B) 2008

C) 2016

Figure 7. North Beach dune is pictured in A) 2005, B) 2008, and C) 2016.

Dune Advance and Slipface Characteristics

Monitoring post data indicates North Beach dune progressively became more active from 2000 to 2004 (Figure 8). At 2004, the dune advanced 0.8 m/year, and then the advance rate gradually declined until 2008. Since then the dune advance rates vary around 0 m/year.

Measurements of the slipface position for 2016 are consistent with the previous data at a -0.02 m/year advance rate.

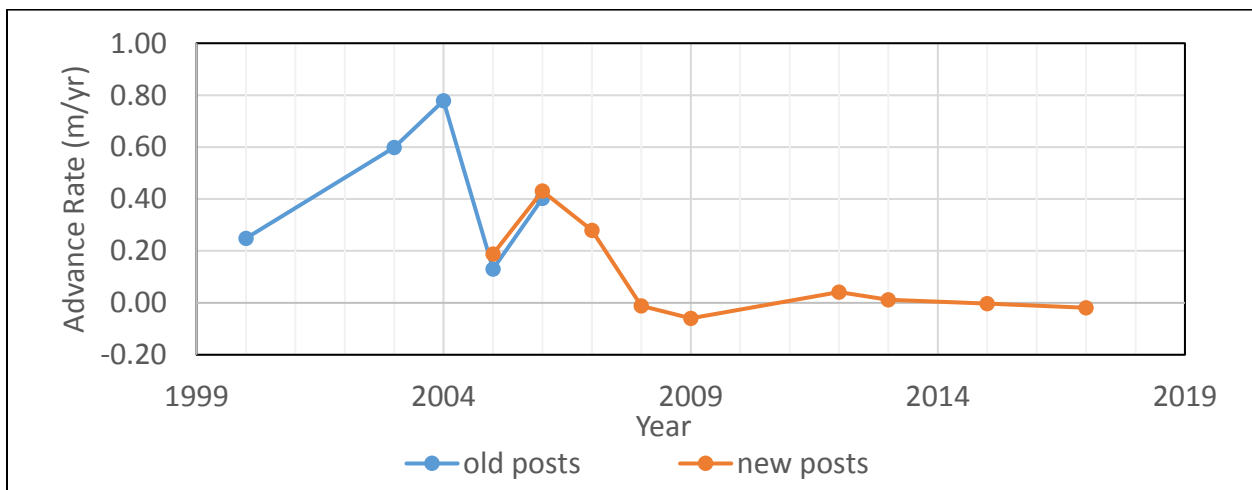


Figure 8. Measured dune advance rates show North Beach dune was moving eastward from 2000-2008 before the rates stabilized around 0 m/year from 2008-2016.

The state of the dune slipface in 2016 is consistent with its measured advance rate. Slipface vegetation consisted of *A. breviligulata* that reached a tallest average height of 78.74 cm and an average health rating of 4.75. The vegetation on the slipface was very similar to the planted vegetation on the upper windward slope, but it had an overall higher health rating. At the upper portions of the slipface there was sparse vegetation while nearer to the bottom it was denser (Figure 9).



Figure 9. The slipface of North Beach dune in November 2016 (photo view is looking down the slipface from the top).

Discussion

Our results indicate the planted vegetation is very similar to the natural communities. The differences in vegetation between the natural and planted communities contained little variation in height and health.

In many studies, species diversity is a big factor in understanding dune ecology, but species diversity results were inconclusive in this study. There was only a two-species difference between the planted vegetation and the natural communities. The planted vegetation was recorded to be a single species, while the natural vegetation had a total of 3 different species. The timing of our sampling, in late fall when some species may have died, may have affected the results of species diversity. Although some studies have shown that species diversity returns slowly (Rozé and Lemauviel 2004), most other studies note significantly more species (Emery and Rudgers 2010; Landi *et al.* 2012).

The ground and aerial photographs that this study used to determine vegetation cover differed in their results, but revealed a trend of increasing vegetation cover over time. One reason for varying results is that the years were different: 2008 and 2016 for ground photos, 2005 and 2014 for aerial photos. The reason the years are different between each method is because this study was limited to the photos that were available. Another reason for differing results is the perspective. On North Beach dune, there is a near horizontal patch of bare sand near the top of the windward slope, which, from a ground view, cannot be accurately seen or measured. Although the two methods produced varying results, both reveal a positive trend in which the vegetation increases over time.

Results from the monitoring posts suggest that since planting dune grass, the dune has been and remains relatively stable. The bare sand at the top and vegetation at the bottom of the slipface suggest a near stabilized dune with some sand transport. If the dune were advancing, there would be fresh sand at the bottom of the slipface; instead, North Beach dune has leaf litter and vegetation at the bottom of the slipface indicative of a stable dune. Although the dune advance rate in 2016 was negative at -0.02 m, the dune is unlikely to be retreating. Instead, because a stabilized dune slipface accumulates large quantities of leaf litter, dune position can be easily misread. Seeing the near zero trend for dune advance indicates a stabilized dune.

Conclusions

Ten years after planting *Ammophila breviligulata* on North Beach dune, vegetation cover on the windward slope has increased by 25-50% so that most of the slope is vegetated. Although there are local areas of sand movement, overall dune activity has stabilized to a dune advance rate of approximately 0 m/year. But species diversity remains higher in natural vegetation areas than the planted areas.

Our study suggests that rehabilitating plant communities will require more than ten years to restore species diversity. Planting vegetation was a positive contributor to stabilizing the windward slope of the dune and slowing dune advance. Apart from species diversity, the similarities in vegetation characteristics between the planted and natural communities show progress towards restoring natural vegetation. We conclude that planting *A. breviligulata* is effective for stabilizing disturbed dune surfaces and restoring a natural vegetation cover.

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Appendix A.

Reference photos from November 2016 for vegetation health ratings from 1 (poor health) to 5 (healthy).

